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BEHAVIORAL TESTING DURING A 7-DAY CONFINEMENT:

THE INFORMATION PROCESSING TASK

by Rollin M. Patton

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SUMMARY

Two subjects were confined for 7 days in a mock-up of a space capsule with a usable volume of 123 cubic feet. A 4-hour-on, 4-hour-off duty cycle was maintained, one subject working and one resting at all times. Various measures of physiological and behavioral functioning were taken. One of the latter assessed performance in a task requiring that the subject act as an information processor. The subject's task was to locate and mark certain designated letters among an array of letters. Task complexity was manipulated by varying the number of designated letters and the ratio of designated to irrelevant letters within the array. The task was performed once each duty period.

The quality of performance of the information processing task is expressed by speed (letters processed per minute) and error (errors per page) scores. Over the course of the confinement, both subjects showed improvement in speed scores, but subject R's error score improved, while subject S's showed no significant change. Subject R's error score was related to time of day, with best performance during his night shift and poorest during his day shift. The effect did not diminish during the latter part of the confinement. Subject S's error score showed no effect related to time of day. Subject S's speed score was related to time of day, with his best performance occurring during the evening and his poorest at night. The effect was more pronounced at the end of the confinement than at the beginning. Subject R's speed score showed no effect of time of day.

Although the speed and error scores were markedly affected by variation in task complexity, the hypothesis that under unfavorable conditions (i.e., nonpreferred shifts) performance of relatively complex tasks would suffer greater decrements than would simple tasks was not confirmed.

Performance of the task was maintained at what appears to be a reasonably high level throughout the 7-day confinement. This result indicates that under the conditions of this study, proficiency in an information processing task can be maintained in a small capsule.

INTRODUCTION

The accomplishment of manned missions into space and plans for more elaborate ventures in the future have increased interest in human response to various unusual situations and operating conditions that will exist. Necessary restrictions of payload weight and size of the spacecraft indicate that the extent of the occupants' bodily movements and perceptual field may be so restricted that their performance will degenerate. Studies of human response to confinement have been performed in various laboratories (refs. 1 to 9). The crew compartment habitability study conducted at the Ames Research Center, of which the testing procedures reported here were a part, was unique in that the confinement capsule realistically simulated, in size and general arrangement, a two-man space vehicle such as is proposed for near-future missions, and closely evaluated a wide variety of behavioral and physiological indices. A description of the habitability study, including its rationale, the procedures employed, and a summary of the results of the various testing procedures, has been presented (ref. 10).

Table I presents a typical on-duty work schedule employed in the study. Seven different performance tasks, indicated in table I by asterisks, were administered sequentially during each duty period. They were selected to represent a typical workload for a 7-day lunar mission. Since the performance tasks were administered independently, each constituted a separate subexperiment within the over-all testing procedure. In addition to the task reported here, the pattern discrimination task has been reported in detail (ref. 11). For convenience, descriptions of the general procedures used in the Ames habitability study have been described in both reports.

In the operation of man-machine systems, an important aspect of man's role is the reception, processing, and distribution of information. Such behavior has been the subject of many studies by psychologists (refs. 12 to 17). Fluctuations of the level of attention in continuous information processing tasks have been demonstrated (ref. 17). Typically, such studies require that the subject locate designated stimuli within an array of these and similar stimuli presented sequentially. It was felt that such a task might be sensitive to certain conditions of the habitability study, specifically, measuring a lowering of attention related to the duration of occupancy of the compartment and/or the time of day at which the task was performed. It was hoped that the test would predict the quality of performance of operational tasks which involve a substantial amount of routine information processing.

PROCEDURE

Two subjects were enclosed for 7 days in a cone-shaped capsule, of approximately 123 cubic feet of usable volume. The capsule contained two seats. One of these could be reclined to provide a cot for the off-duty subject. One subject at a time could stand behind the seats, and exercise moderately. Except for volume, all physical aspects of the environment (heat, ventilation, illumination, etc.) accorded with usual requirements for human comfort. Some insulation was provided to diminish noises from the outside environment. The illumination of the compartment was controlled by the subjects.

Duty cycles were an alternating 4 hours on, 4 hours off, with one subject on duty at all times while the other rested. On-duty shifts were:

12 Noon - 4 P.M.	Subject S, Day shift
4 P.M. - 8 P.M.	Subject R, Evening shift
8 P.M. - 12 Midnight	Subject S, Evening shift
12 Midnight - 4 A.M.	Subject R, Night shift
4 A.M. - 8 A.M.	Subject S, Night shift
8 A.M. - 12 Noon	Subject R, Day shift

A variety of performance tasks were given the on-duty subject. Tasks requiring information processing, the estimation of the rate of a pointer movement, vigilance, pattern discrimination, navigation computation and tracking were administered. The total time required for these procedures was slightly over 3 hours of the 4-hour duty period.

The information processing task was administered once each on-duty period, during the third hour. During each shift, a loose-leaf binder containing worksheets on which the test material appeared was placed in the capsule and removed via a pass-through arrangement. Ten worksheets, all different, were used each time. Each worksheet presented an array of 800 typed capital letters. The letters were arranged in 16 double-spaced rows of 50 letters each. A letter (or letters) chosen from among those appearing in the array was hand printed at the top of that worksheet and was much larger than those in the typed array (1/2 inch high). It was the subject's task to locate this letter (hereafter called a designated letter) wherever it occurred in the array, and to indicate such a letter by drawing a vertical line through it. A designated letter appeared many times in the array. A typical worksheet as it appeared after processing by the subject is shown as figure 1.

Task complexity was manipulated by varying the number of different letters in the array (6, 12, or 24) and the number of designated letters (1, 2, or 4). Five such combinations were used:

	Letters in array	Designated letters
I	24	1
II	24	2
III	24	4
IV	6	1
V	12	2

Thus two sequences could be derived. The I, II, III sequence presented ratios of 1:24, 2:24, and 4:24, and is called the array-constant sequence.

Within this sequence, task complexity was varied, but the complexity of the material to be processed was held constant. The number of designated letters appearing within the array varied. The IV, V, III sequence presented ratios of 1:6, 2:12, and 4:24 and is called the ratio-constant sequence. Within this sequence also task complexity was varied, but the number of designated letters in the array remained constant (1:6, an average of 133 in the 800 letters of the array).

The letters G and Q were never used in the arrays; thus 24 letters were available for the largest arrays. The letters used in the 6- and 12-letter arrays were chosen from among the 24 available by a random-number procedure. There was no particular order of letters in the array; they were arranged by striking the appropriate typewriter keys in a chance sequence.

In all, 15 different arrays were developed: three 6-letter; three 12-letter; and nine 24-letter. Since the 24-letter test form was presented 3 times as often as the others, the greater number of 24-letter test forms allowed each of the 15 forms to be presented equally often.

The order in which the various conditions were presented during a session and the particular array to be used were determined from a table of random numbers. Repetition of a ratio within the first 5 pages, or within the last 5 pages, was not allowed. Thus each of the ratios appeared once in the first 5 pages of the booklet, and each appeared once in the second 5 pages.

A table of random numbers was also used to select the required number of designated letters from among the available letters in the array. For example, figure 1 represents an array of 12 letters in which two designated letters must be located. The 12 letters used in this case are O, I, B, J, Y, T, M, E, W, S, X, and D. The two designated letters, T and B, were chosen from among these by a random process.

The subject accomplished the task by scanning the top row of the page, then the second row, and so on to the bottom of the page. Upon completing a page, he turned immediately to the next page and repeated the process. For conditions II, III, and V he was asked not to locate all of one letter, then all of another, but to scan the array once, looking for all designated letters simultaneously.

The subject worked continuously at the task for 24 minutes. The experimenter spoke the word "circle" to the subject at one-minute intervals at which time the subject drew a circle around the letter he was regarding at the moment. Speed of task performance was measured by the number of letters appearing between consecutive circles on one page. Where three or four circles appeared on a page, the mean value was computed. The reason for the particular approach to the speed score was that the investigator hoped to detect increases or decreases in speed on each page. As it turned out, the data were insufficient for such an analysis.

Designated letters not marked were scored as errors.

The subjects were not instructed to try either for maximum speed or maximum accuracy, but to "perform the work as well you can, working as rapidly and as accurately as possible." Performance of a task such as this is extremely sensitive to any instructions to achieve either maximum speed or maximum accuracy, since inevitably one must be gained at the expense of the other. The instructions were designed deliberately to allow the subject himself to choose his level of performance relative to speed versus accuracy.

Because of time limitations prior to the confinement, no pretraining in the task was given.

RESULTS AND DISCUSSION

The subjects seldom completed many of the latter 5 pages of the test booklet. Consequently, only the first 5 pages could be used in the analysis. Because of the constraint in sequence previously mentioned, each of the five ratio conditions appeared once in the first 5 pages.

Speed of performance is expressed as mean number of letters processed per minute. Accuracy is expressed as number of errors per page. To facilitate comparisons, the scale for error is inverted, so that in all figures an upward movement of the curve, or a relatively higher position, indicates better performance (faster or fewer errors), while a downward movement of the curve, or a lower position, represents poorer performance.

Preliminary inspection of the data indicated that the requirements for the use of parametric tests for the various comparisons were not met. Consequently, the significance of various observed differences was tested by nonparametric methods only. The tests used were the Mann-Whitney U Test and the Friedman Two-Way Analysis of Variance by Ranks.

The Mann-Whitney U Test (ref. 18, pp. 116-127) develops a statistic (z) which allows a statement of the probability (p) that two independent samples could have been drawn from the same population.

The Friedman Two-Way Analysis of Variance (ref. 18, pp. 166-172) develops a statistic (x_r^2) which allows a statement of the probability (p) that k (3 or more) samples could have been drawn from the same population. The value of p for a given x_r^2 is a function of the number of degrees of freedom (df), with $df = k - 1$.

Day-by-Day Performance

Figure 2 presents the speed scores separately for subjects S and R for each day of the confinement. Each point plotted represents a mean value for all shifts and all experimental treatments.

Both subjects' scores show an over-all improvement during the course of the confinement. This trend was tested by comparing the scores made by each subject on days 1 to 3 with those made on days 5 to 7. For both subjects, the difference in the scores is significant (U Test: subject R, $z = 4.35$, $p < 0.001$; subject S, $z = 5.36$, $p < 0.001$).

In general, subject S worked more rapidly than subject R (U Test, $z = 2.60$, $p < 0.005$).

Figure 3 presents the error scores separately for subjects S and R for each day of the confinement. Each point plotted represents a mean value for all shifts and all experimental treatments.

Again, a comparison of the earlier part of the run with the later (days 1-3 vs. 5 - 7) shows that subject R exhibited a decrease in error, while subject S showed no significant change (U Test: subject R, $z = 2.58$, $p < 0.005$; subject S, $z = 0.23$, not significant).

In general, subject R made fewer errors than subject S (U Test, $z = 3.74$, $p < 0.001$).

Main Effects of Time of Day (Shift)

Interest existed in discovering differential effects of the various shifts upon performance. The main effects of shift are plotted in figures 4 (speed) and 5 (error). Subject R shows no effect of shift on speed. Subject S does, his best-to-worst order of shifts being evening, day, night (Friedman Test, $x_r^2 = 9.06$, $df = 2$, $p < 0.02$).

Subject R's errors were significantly affected by shift. His best-to-worst order is night, evening, day (Friedman Test, $x_r^2 = 6.18$, $df = 2$, $p < 0.05$). The observed differences for subject S are not significant.

It will be noted that in the cases of both subjects, significant effects of shift occurred for the measure in which the subject excelled. Subject S worked more rapidly than R, and his speed was related to shift. Subject R made fewer errors than S, and his error production was related to shift. Further research is needed to determine if this relationship is significant.

Subject performance on particular shifts may be related to their typical manners of working. Subject R is a physiologist, accustomed to working under peaceful conditions, commonly late at night. He worked well from midnight to 4 A.M., when S was asleep, and perhaps was disturbed by the greater general activity during the 8 A.M. to noon shift. Subject S is a test pilot, and is accustomed to performing as a subject in experimental situations which are anything but peaceful. He performed relatively well during the day, relatively poorly at night. It is possible, however, that under the conditions of the experiment, with the maintenance of a pronounced day-night routine (a point to be discussed later), the 4 A.M. to 8 A.M. shift was inherently more taxing than the midnight to 4 A.M. shift. Had the subjects' shift assignments been reversed, the result might have been different.

Interactive Effects: Days vs. Shifts

It might be hypothesized that under such a regular 4-hour-on, 4-hour-off schedule, day-night effects would tend to disappear in time, the subjects sleeping as needed during their 4-hour off-duty periods, each 8-hour duty cycle becoming, in effect, the subject's day. If this occurred, shift differences should be less pronounced at the end of confinement than at the beginning. Figures 6 and 7 present data for the beginning (first 3 days) and end (last 3 days) of the confinement separately. Only those data which showed over-all significant differences were considered in this way.

Figure 6 presents subject S's speed scores, by shift, comparing beginning and end of confinement. The scores recorded during the first 3 days do not differ significantly by shift (Friedman Test). Those for the last 3 days do (Friedman Test, $x_r^2 = 9.74$, df = 2, $p < 0.01$). It seems reasonable to conclude that most of the observed shift difference occurred during the latter days of the confinement. This is contrary to the hypothesis, in that shift differences became more pronounced with the passage of time.

Figure 7 presents subject R's error scores, by shift, comparing the first with the last 3 days. There is a suggestion that greater effects of shift were associated with the last 3 days, but neither analysis reveals statistical significance (Friedman Test: first 3 days, $x_r^2 = 2.23$, df = 2, p between 0.30 and 0.50; last 3 days, $x_r^2 = 4.14$, df = 2, p between 0.10 and 0.20). It appears reasonable to believe that shift effects did not disappear over the course of the 7 days.

The persistence of shift differences is explainable, at least in part, by the abundance of time-of-day cues available to the subjects during the confinement. These reminders included the presence of timepieces, the presence in the capsule of an experimental schedule marked in real time, day-night variation in audible external noise, etc. Even were these factors controlled, the confinement experience is strongly related to number of days duration, and inevitably the subjects would be interested in number of days since the beginning, number of days until the end, or both. Space missions themselves are invariably related to duration in days, so that it is possible that any shift effects that might exist at the beginning of the operation would persist. It is entirely possible, of course, that because of obvious difference in task structure and general situation, no shift differences would exist during the actual mission. The point seems worthy of further study.

Effects of Task Complexity

Figure 8 presents the speed scores separately for subjects as a function of task complexity. Under both array-constant and ratio-constant conditions, speed tended to decline with increased complexity (Friedman Test: array-constant conditions, $x_r^2 = 76.4$, df = 2, $p < 0.001$; ratio-constant conditions, $x_r^2 = 56.9$, df = 2, $p < 0.001$). Performance under the three conditions (1:6, 2:12, and 4:24) that required a great number of marks was relatively slow. This is to be expected, since the act of making the marks is in itself time consuming.

Figure 9 presents the error data, separately for subjects, as a function of task complexity. Increased complexity led to a regular increase in error, under both array-constant and ratio-constant sequences (Friedman Test: array-constant conditions, $x_r^2 = 68.1$, df = 2, $p < 0.001$; ratio-constant conditions, $x_r^2 = 48.4$, df = 2, $p < 0.001$).

A particular hypothesis of the experiment was that interactive effects between shift and task complexity would be observed. That is, it was thought that decrements related to a particular shift might be more pronounced during performance of relatively complex tasks. The desire to test this hypothesis was the primary reason for including complexity as an experimental variable.

No such interaction was observed.

General Evaluation of Performance

Over the course of the confinement both subjects showed an improvement in speed and no decrement in error. Since the task was developed just prior to the beginning of the confinement, there was no possibility of pretraining the subjects. Consequently, the effects of learning cannot be separated from the effects of the confinement, and it is possible that improvement through learning could be hiding decrements due to confinement. Nevertheless, it seems significant that continuing improvement did occur, and that any stresses of the confinement experience were insufficient to overcome this trend. It is believed that the results of this task support the conclusion that the capsule configuration tested is habitable, under the conditions of this experiment, since proficiency in an information processing task was maintained during a 7-day continuous occupancy.

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif., April 26, 1963

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TABLE I.- SAMPLE WORK SCHEDULE

Shift No. 20
Monday, April 2, 1962
Subject R on duty

4:00 P.M.	Medical monitoring
4:15	*Rate estimation
4:35	*Vigilance
4:45	*Pattern discrimination
5:10	*Mission status monitoring
5:15	*Navigation
6:10	Rest period
6:25	*Tracking
6:45	*Information processing
7:15	*Vigilance
7:25	*Pattern discrimination
7:50	Rest
8:00	Off-duty period begins

*Performance task

TB

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Figure 1.- A sample worksheet, condition V.

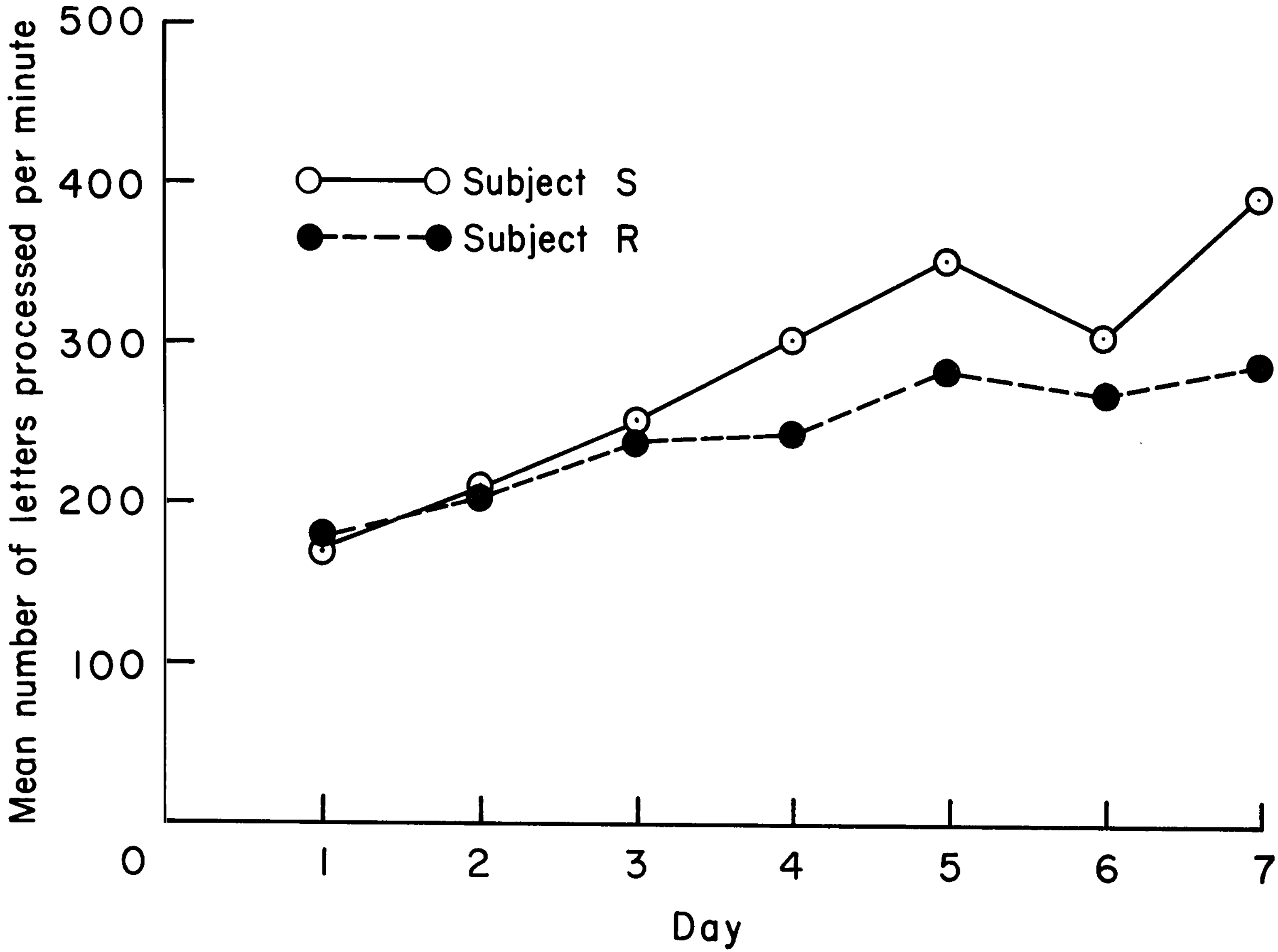

Figure 2.- Speed of performance by days.

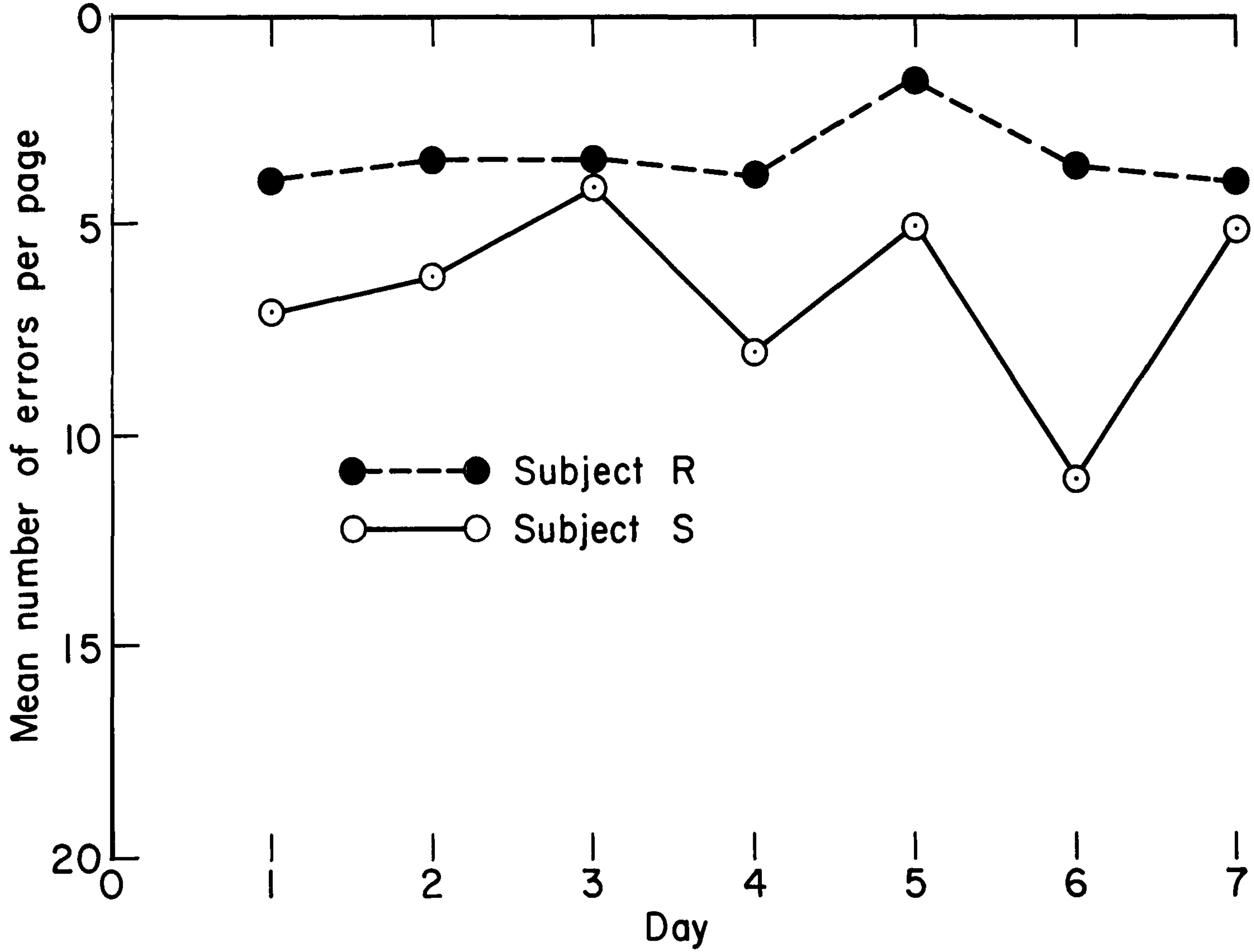

Figure 3.- Accuracy of performance (error measure) by days.

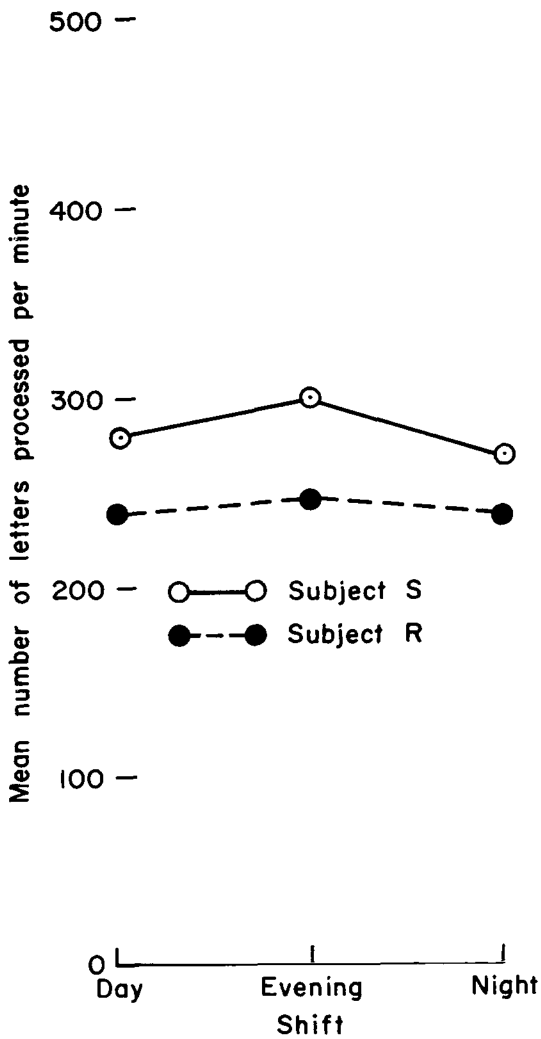

Figure 4.- Speed of performance as a function of shift. Points plotted are average for all 7 days, all conditions.

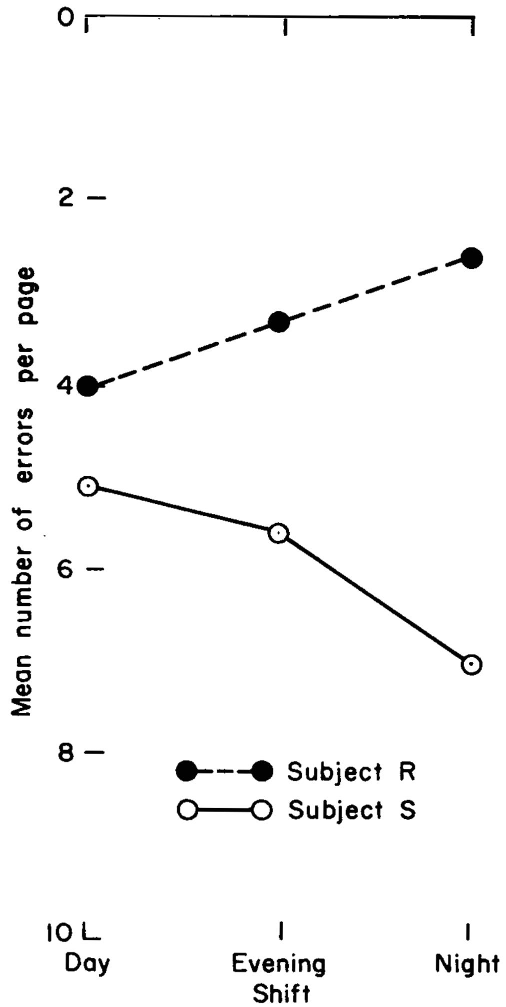

Figure 5.- Accuracy of performance (error measure) as a function of shift. Points plotted are average for all 7 days, all conditions.

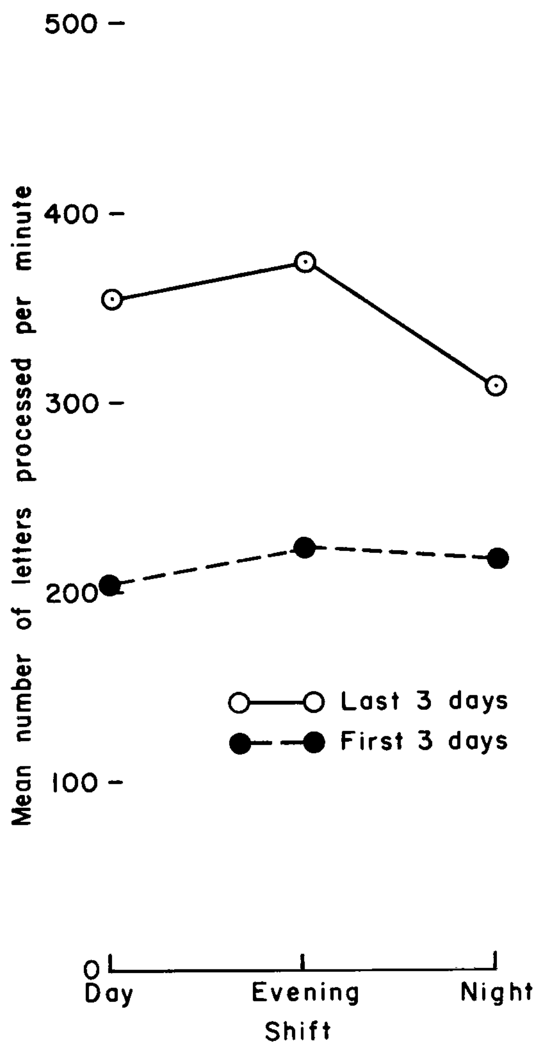

Figure 6.- Speed of performance as a function of shift. The beginning of confinment (days 1-3) is compared to the end of confinement (days 5-7). Data from subject S only.

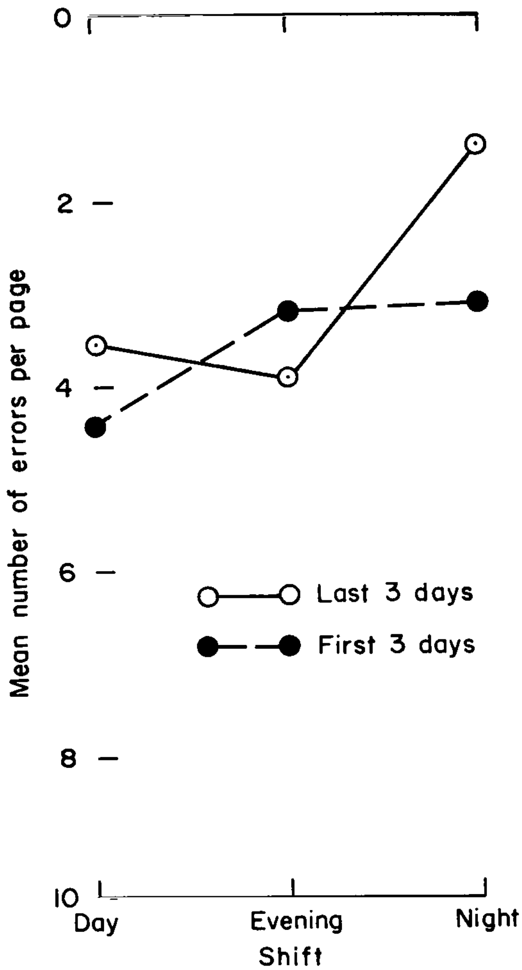

Figure 7.- Accuracy of performance (error measure) as a function of shift. The beginning of confinement (days 1-3) is compared to the end of confinement (days 5-7).

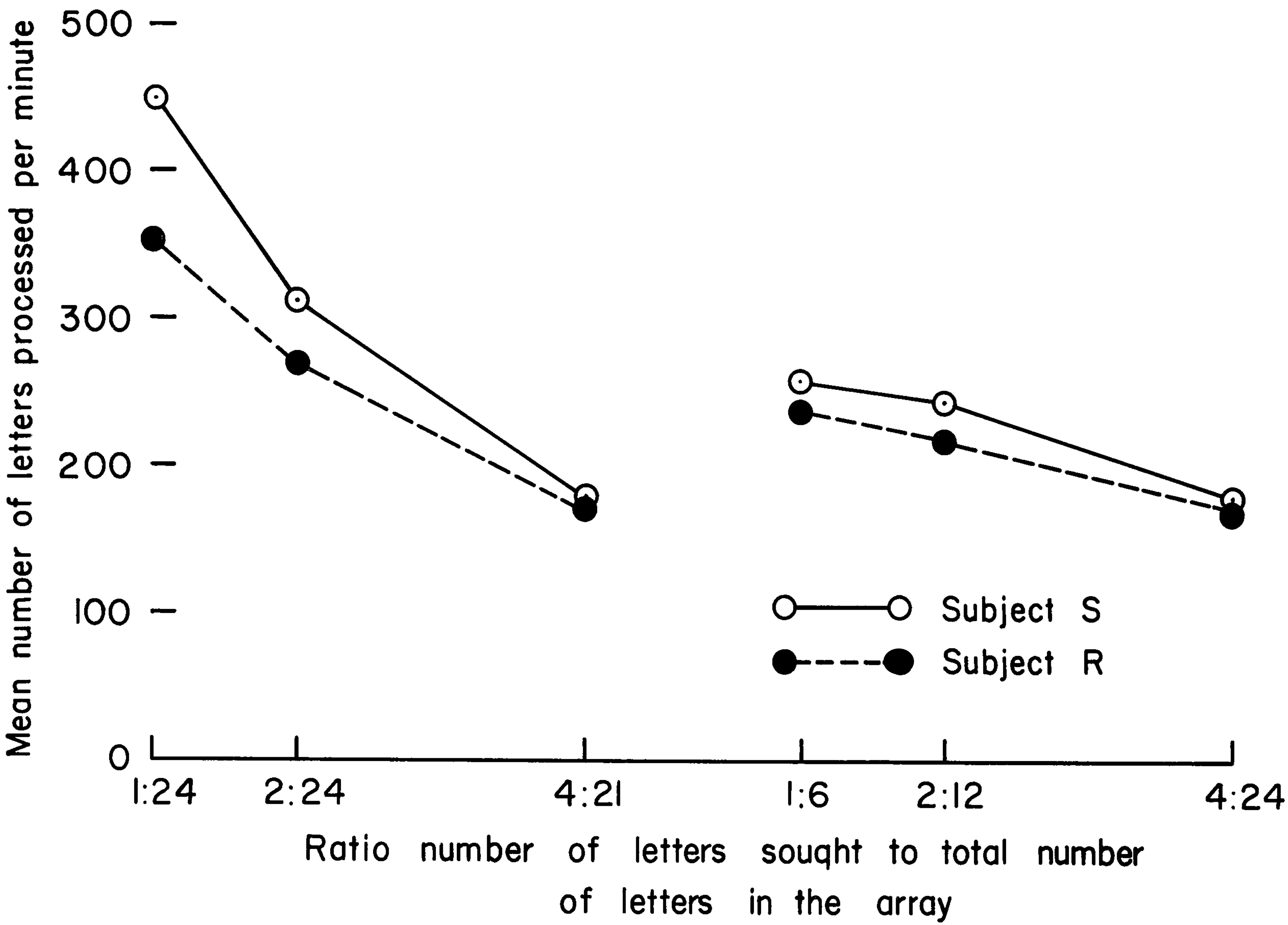

Figure 8.- Speed of performance as a function of task complexity.

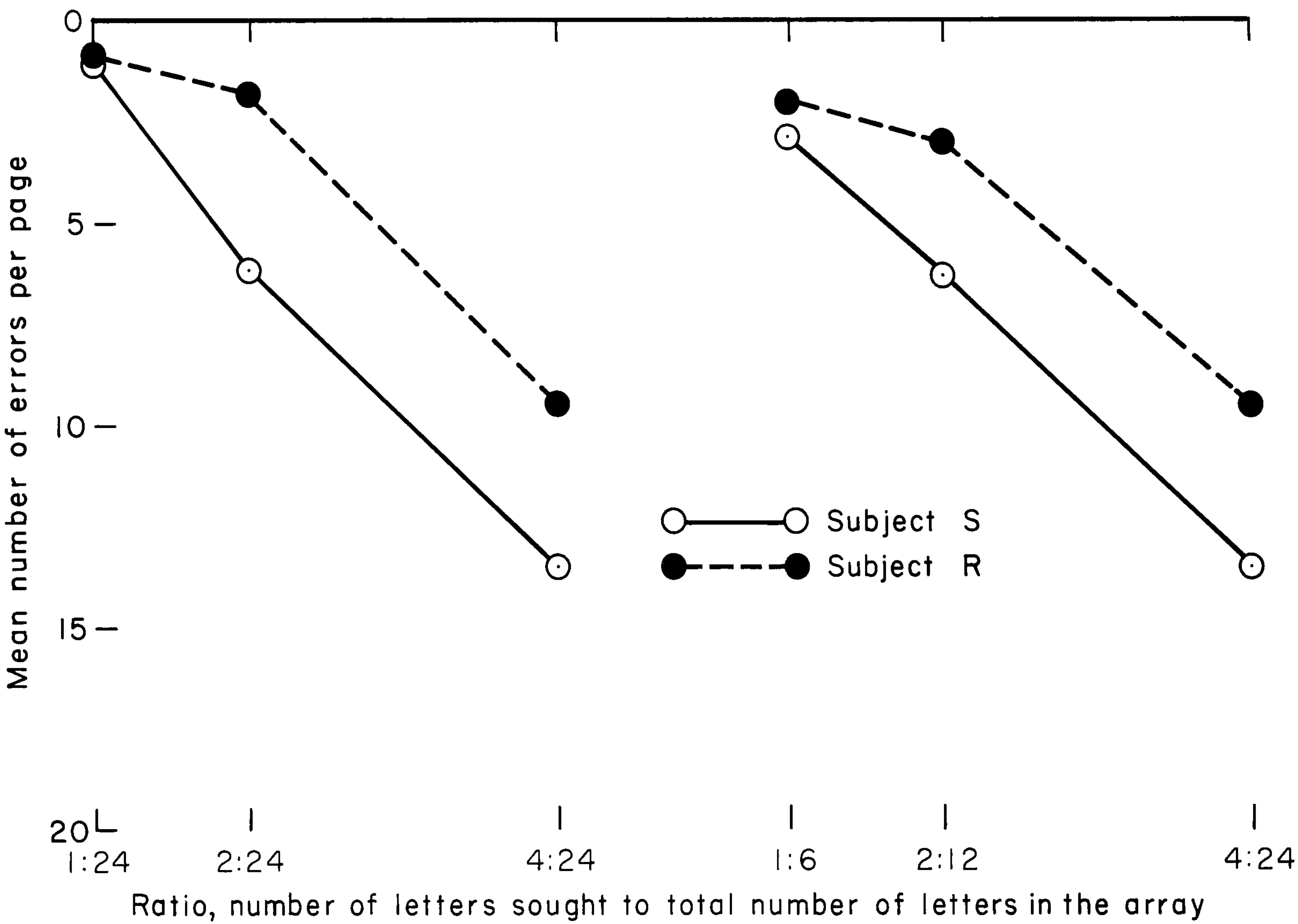

Figure 9.- Accuracy of performance (error measure) as a function of task complexity.

NASA-Langley, 1963 A-791